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**Review of the Lehua Island rat eradication project 2009**

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## Summary

### Background

The eradication of introduced mammals is a prerequisite for a larger program to restore biodiversity on 126-ha Lehua Island, Hawaii. Rabbits were eradicated by 2006 and an attempt was made to eradicate the remaining species, the Polynesian rat (*Rattus exulans*), in January 2009. Planning for the eradication of rats began in 2005 and covered legislative, regulatory, environmental risk assessment, operational and contingency response aspects of the project. Aerial application of rodenticide baits, the most commonly used (and sometimes only practical) method to eradicate rodents on large or topographically challenging islands, was chosen as the method for Lehua Island. Two rodenticide baits containing brodifacoum and one containing diphacinone rodenticides are registered for aerial application on islands in the USA. The particular history of rodent control on the larger islands, public sentiment, and the policy climate in Hawaii meant the use of diphacinone was favored for the Lehua project.

The use of diphacinone has some major advantages over brodifacoum in eradicating island rodents (and for sustained control when eradication is not feasible) largely because its toxicity and environmental persistence confers lower hazard to non-target wildlife. However, diphacinone does not have such an established operational history as brodifacoum, particularly when baits are broadcast from the air. An analysis of 206 previous eradication attempts against five species of rodents on islands using brodifacoum or diphacinone is presented in an appendix to this report. For all methods, 19.6% of 184 attempts using brodifacoum failed, while 31.8% of 22 attempts using diphacinone failed. This difference is not statistically significant (Fisher's Exact Test  $P = 0.26$ ). The two toxins have similar failure rates for ground-based operations (29% for brodifacoum and 23% for diphacinone; Fisher's Exact Test  $P = 0.77$ ). The limited evidence suggests aerial baiting using brodifacoum has a lower failure rate (11% of 93 attempts) than for diphacinone (75% but of only 5 attempts) (Fisher's Exact test  $P = 0.010$ ). However, we caution against drawing firm conclusions about these differences because of the small sample size for the diphacinone attempts.

The attempt to eradicate rats from Lehua Island was therefore a logical step in expanding the 'track record' for effective use of diphacinone in eradicating rodents. However, 7 months after two aerial applications of diphacinone bait, Polynesian rats were found on Lehua Island, indicating that the operation had failed – or that rats had reinvaded the island, or both.

In early April 2010, the Research Corporation of the University of Hawaii on behalf of the Hawaii Department of Land and Natural Resources contracted Landcare Research to review the Lehua Island rat project. The senior author visited Hawaii between 17 and 21 April 2010 to discuss the project, and followed this with email and telephone dialogue with the aim of providing a draft report for comment by 13 May 2010. This draft report was revised following comments by internal referees and Hawaiian stakeholders.

## **Objectives**

The objectives of this review as contracted and revised at a Lehua Rat Eradication Partners Meeting on 16 April 2010 were to:

- (a) Review the planning, implementation and monitoring of the Lehua rat eradication project, including:
  - The sub-project on rat genetics
  - Evaluation of biosecurity plans
  - The aerial baiting permit and conditions requiring that no bait entered the sea, and whether this succeeded
  - Non-target-animal residue testing
  - Outreach and communications timeline
- (b) Suggest changes that would improve the likelihood of success in the future.

## **Results**

### *Planning and implementation*

The planning process was thorough and included contingencies to search for survivors and react if the proposed double baiting with diphacinone failed to kill all the rats. These contingencies for immediate reaction (cf. the wait-and-see-after-2-years strategy generally used for brodifacoum operations) were sensible given the limited precedents using diphacinone in aerial baiting. In the event, there was no formal search for surviving rats immediately after the last baiting as funding was not set aside to do it – whether there was any technical capacity to reliably detect survivors in such a situation is unclear. Eight months later when the rats were abundant enough to easily detect the capacity to react was absent. This lack of capacity appeared to be in part due to lack of ongoing funds, in part indecision by agencies on how to react appropriately, in part due an internal decision by the regulatory agency in February 2009 not to issue further permits for aerial baiting in Hawaii (the Lehua permit apparently expired on 1 March 2009), and in part because of ongoing policy and legal issues around the formal investigation of fish deaths coincident with aerial baiting.

In summary, the planning process consisted of:

- An initial Environmental Assessment (2005) that specified the use of brodifacoum baits as a contingency if monitoring showed rats had survived the two applications of diphacinone baits. However, this option failed to take account of Hawaiian regulatory and social aversion to the use of brodifacoum and the option was not considered in subsequent plans.
- A revised Environmental Assessment (2008) that placed a caveat on the contingent use of brodifacoum in the event of failure of the diphacinone baiting. This caveat was that proof would be required that it was the rodenticide (diphacinone) that was the cause of failure, not the way it was applied. This proof was (and remains) intrinsically impossible to demonstrate. The revised plan also changed the optimal season for baiting in light of research on the breeding seasonality of the rats.

- In any event, the subsequent operational plan did not revisit the brodifacoum option (presumably on the grounds that its use would not be permitted) but did suggest contingency actions involving further aerial baiting using diphacinone should rats be found after the initial applications. Bait was available to do this but the subsequent monitoring for survivors (intended for mid-2009) was not funded and then was overtaken by the *ad hoc* discovery of rats in August 2009. This timing did not allow for any aerial reaction to failure within a few weeks of the last bait drop, i.e. to fit within the permit expiry date of March 2009 (quoted in error as March 2008 in the permit). The permit was itself overtaken by the imposition of aerial baiting bans by the Pesticides Branch of the Hawaii Department of Agriculture on 5 February 2009 until general conditions around testing guidelines for rodenticides impacts in marine environments were developed by the Federal agency, the EPA.
- Ideally, the intention to use up to two extra diphacinone aerial broadcasts should be explicit in plans, with a contingency NOT to use them as required by the absence of evidence of rat survival. This would still have implied the capacity to detect any survivors (or lack of them), but the capacity and intent to deploy the extra effort would have been set.
- It is unclear whether this precautionary strategy of up to four broadcasts would comply with the EPA label requirements that allow such extra broadcasts IF survivors are found. If a strict interpretation of the label condition is applied, the response to survivors would have to remain reactive and some more determined effort to detect rats should have been made immediately (weeks not months) after the second baiting. However, the probability of detecting any rat when either none or very few are present is low given the search effort practicable on Lehua, and there would be no ability to target any remedial action short of re-treating the whole island. Thus, the label conditions and biological reality diverge.
- In an additional complexity, (a) the death of non-target feral pigs after an experimental and off-label use of diphacinone baits at Keahou Ranch in 2003, (b) the coincidental appearance of whale carcasses washing ashore on Maui in 2008 after the Mokapu Island operation, and on Niihau and Kauai after the Lehua Island operation and (c) fish deaths on Niihau after the Lehua operation led the State regulatory agency to instruct its staff (on 5 February 2009) not to authorize any further aerial applications of rodenticides. This presumably would not have halted any planned aerial baiting reaction to survivors on Lehua, approval for which was implied by the current permit based on the permit application for four ‘tentative dates of application’ in January 2009. However, the timing of this decision and the inherently negative sentiment expressed by it presumably added indecision to reduced response capacity for the Lehua project managers.
- The condition that no bait was to be applied directly to water imposed by the State permit to use aerially-sown baits was made late in the planning process. It was reported to us that a condition that no baits should be laid within 30 m of the water was required. This condition does not appear on the permit issued on 1 December 2008 and it is unclear to us whether it was an operational decision to meet the ‘no baits directly into the sea’ condition or some later instruction from the regulator.
- Ongoing consultation with the State pesticide regulators was planned and partially conducted. The Pesticides Branch saw, for example, the flight path data but the

proposed presence of a Branch member during at least one of the aerial drops did not take place.

- A major outreach program was planned and conducted from late 2003 but with a focus on the rat eradication mid-2008. The proactive outreach demonstrating the wider restoration goals for the island, the benefits of rat eradication and explaining how it was to be done was extensive, but possibly began too late. It was overtaken by the need to react to events after the operation – the fish kills and eventually the failure to eradicate the rats.
- Monitoring of non-target species was planned but only conducted for the marine animals.

### *Diagnoses of failure*

- Rats were eradicated but reinvaded?

Preliminary results from allelic analyses show the pre- and post-baiting rats on Lehua Island could be from the same population, and so the rats found in August 2009 were probably survivors. However, confirmation of this conclusion depends on the results of the allele frequencies of rats from potential source islands.

- Rats survived due to an operational issue
  - The bait manufacturer tested the baits and provided a guarantee of their quality. No independent quality assurance was conducted.
  - The spatial coverage of baits in the two drops was constrained by the permit instruction that no baits were to fall directly in the sea (or within 30 m of it). How this was interpreted by the pilot and operational manager is unknown but the GPS maps of the flight paths and subsequent analyses of bait swaths suggest at least one gap of at least 30 m occurred, although this was a tidal platform washed by the sea.
  - The application of the bait following an unusual rainfall event in December that triggered a flush of green vegetation and may have compromised the project by providing rats with more abundant natural food that might have been more palatable than the cereal baits.
- Rats survived because of the toxin used?
  - There is no evidence one way or the other that diphacinone per se was the cause of failure. If rats eat enough bait with this toxicant often enough they will all die.
- Rats survived because an interaction between baiting strategy and the toxin's mode of action?
  - Rats are required to feed daily on diphacinone baits over several days to obtain a lethal dose. Gaps in broadcast application, gaps in bait availability if individual rats ate most of the bait in some areas leaving others with insufficient bait, or competition with natural foods (or combinations of these) may have meant that some rats did not get the required consecutive daily dosage of toxicant to kill them.



These possible explanations cannot be further teased apart, although we note the presence of survivors (albeit 6 months after the baiting) in areas away from the coast and that had received most baits suggests sowing gaps were not the problem – assuming no redistribution of the survivors from putative gaps into the areas they were found.

In summary, the actual delivery of the bait across the island was well planned and executed, especially given the difficulties in accessing full-time staff and the constraints placed on bait distribution by the regulators. However, in retrospect we identify two issues of timing that may have been critical. First, the decision to begin after unseasonal rain and when regulatory conditions were imposed increased the risk of failure, although delay in the face of logistical momentum was difficult. Second, the inability to trigger the planned reaction to evidence of surviving rodents within the window of opportunity imposed by the permit (sometime between the last baiting and 1 March 2009) meant the failure of the two aerial baitings could not be salvaged. Different reactions using ground-based methods may have been permitted but decisions to react seem to have been confounded by other issues such as funding and the regulatory concerns over the fish deaths. Given the difficulties in detecting survivors at an early stage, a precautionary rather than reactive application might have been best, if it met the EPA label requirements for evidence of survival.

## **Recommendations for the future**

1. The EPA label requirements for repeat applications of diphacinone need to be revised to allow for a precautionary approach, i.e. further broadcasts or other applications should be permitted unless there is a clear absence of survivors. Managers need to invest in developing monitoring methods with known detection characteristics that can be applied soon after the second aerial baiting and that give a high probability that any survivors would be detected, to enable a reactive approach to be triggered or to provide evidence of absence.
2. Studies need to be conducted to address public and regulatory concerns about the risk of diphacinone baits to marine fish. We do not think this is a high risk but regulators and the public need to be convinced. It is hard to see how one would do similar tests on cetaceans or pinnipeds, but common sense suggests exposure is highly unlikely and thus the risks low.
3. An analysis of the outreach program to assess the changed perspectives among those who might naturally support a rodent eradication as a step to improving the island's biodiversity and those who might focus more on the operational risks would be worth doing to inform future projects.
4. Given the explicit experimental nature of aerial broadcast with diphacinone, pre-operational field trials using non-toxic baits with a bait marker would help to determine if the abundance of natural food is likely to compromise success. A quantitative bait marker would have to be used to determine lethal acceptance rates for diphacinone baits.
5. A ground-baiting operation using either hand-broadcast baiting or bait stations (or a mix of both) seems the only practical way forward on Lehua Island in the short term. Diphacinone baits seem to have a good chance of success with this method providing coverage is sufficient to give all rats a chance for long-term exposure to baits. The constraints on this method are that the island is topographically difficult yet all bait

stations or baited sites will need to be maintained with a certain supply of baits for several weeks, i.e. multiple visits will be required.

6. If the aerial broadcast method is to be repeated the operation should not start if natural food is abundant. This would require flexibility in planning, funding and regulatory processes. If the permits require no baits fall directly in the sea remains, either the coastal gap should be baited by hand broadcast or bait stations and/or the behavior of coastal rats should be studied to determine the frequency with which they venture into potentially baited areas. This could be done by telemetry studies or by the use of bait markers in non-toxic baits. Finally, a protocol to detect and map the location of survivors would need to be developed to enable the reactionary application of further baiting – unless the EPA label conditions can be changed to allow for a precautionary approach. Developing a search and detection protocol with sufficient power to find and locate survivors with high confidence is not a trivial task.
7. The complex governance and decision-making processes involved in planning, regulating, delivering and monitoring the Lehua Island project need to be streamlined in future projects so that who does what for whom is transparent. The nature of the relationship between the proposing and funding agencies (USFWS and DOFAW) and the delivery agencies (Wildlife Services of USDA) was essentially one of client and contractor. Whose role should it be to manage the relationships with regulators or with stakeholders? This was not always transparent and it appears some of these functional relationships were not covered.
8. More generally, it appears that the tested double-baiting strategy used for aerial application of brodifacoum baits cannot be simply copied for diphacinone aerial baiting. More complex data on ensuring exposure time for all rats than have been gained in the trials with diphacinone conducted for sustained control operations will be required. Put simply, LD50s and average exposure requirements are relevant to sustained control but LD100s and the tails of distributions are critical for eradication.
9. Decisions on whether to start an operation using diphacinone baits might have to be more strict than for those using brodifacoum if, for example, competition with natural food and its availability is a factor in bait acceptance by rats.

## 1 Introduction

An attempt to eradicate Polynesian rats (*Rattus exulans*) from Lehua Island (126 ha) in Hawaii in January 2009 using aerially broadcast baits containing the rodenticide diphacinone failed. At the time, this was only the fourth attempt at eradicating rodents using this method. The first in 2008, also against Polynesian rats on the small islet of Mokapu also in Hawaii, succeeded, but attempts in 2008 against *Rattus rattus* on three islands in the Ogasawara group in Japan apparently failed as these islands were rebaited in 2010 – with unknown outcomes. The reasons for the failure on Lehua Island were not immediately clear and a response to re-attempt the eradication has been delayed.

In early April 2010, the University of Hawaii contracted Landcare Research to review the Lehua Island operation to determine if the causes of failure could be diagnosed and to recommend options for future eradication attempts on Lehua Island. The senior author visited Hawai'i between 17 and 21 April 2010 to discuss the project with stakeholders, and followed this with email and telephone dialogue with the aim of providing a draft report by early June 2010. This final version was produced in January 2011 after comments on the draft from Hawaiian stakeholders.

## 2 Background

Rodents have been eradicated from over 500 islands around the world (Howald et al. 2007; Parkes unpubl. data) with significant benefits to the native biodiversity on most of these islands (e.g. Rauzon 2007).

Second-generation anticoagulants have been the most commonly used rodenticides (Howald et al. 2007). These compounds are very effective at killing rodents, which generally ingest a lethal dose on first feeding from only a few of the standard cereal baits. The delayed onset of symptoms means rats continue feeding even when they have ingested a lethal dose. However, the most toxic anticoagulants, such as brodifacoum, pose high primary hazards to non-target mammals and birds that eat the baits. Brodifacoum also remains in the carcasses of lethally poisoned rodents, and also has prolonged persistence and corresponding potential for bioaccumulation in the liver of mammals and birds that survive exposure (e.g. Fisher et al. 2003). This creates a risk of secondary poisoning for rodent predators or scavengers that eat poisoned carcasses (Erickson & Urban 2004), and in some instances for insectivores that eat invertebrates that have eaten baits (Dowding et al. 2006). In previous eradications using broadcast baits with brodifacoum, these non-target risks were often accepted on the cost–benefit assumption that any negative population effects incurred through non-target mortality were soon remedied for species affected by the rodents by the removal of rodents, or by rapid recolonization (e.g. Griffiths & Towns 2008). Often the risks can be avoided completely or to a large extent simply by applying the baits at times of year when potential non-target species are absent or rare, e.g. when seabirds are not nesting or are absent. Where risk, at least at a population level, is unacceptable (biologically, legally or politically) active mitigation has been successful, e.g. endemic dormice (*Peromyscus maniculatus anacapae*) were held in captivity during the *R. rattus* eradication on Anacapa Island and released when the risk was over (Howald et al. 2009). Recent non-target primary and secondary mortalities of gulls and bald eagles following aerial baiting with brodifacoum on Rat Island in Alaska (Ebbert in press; Ornithological Council 2010) mean US decision-makers now also have to be cautious

about using brodifacoum - to comply with the EPA label regulations on non-target hazards for this toxin as well as to take notice of public perceptions.

Diphacinone is a first-generation anticoagulant with the same mode of toxic action and delayed onset of symptoms to brodifacoum, but it has a reduced risk of poisoning non-target species. Birds are less susceptible than mammals to diphacinone (e.g. Erickson & Urban 2004), so the primary hazard of diphacinone baits to them is less than for brodifacoum. Importantly, diphacinone also has a much shorter persistence in rodent liver than brodifacoum (Fisher et al. 2003), so that its secondary hazard to non-target predators and scavengers is further reduced through this combination of lower toxicity (to birds) and low environmental persistence. This is an important advantage over brodifacoum and therefore a credible criterion for selection of diphacinone for island eradications. However, the lower toxicity of diphacinone requires target rodents to eat baits over several days to obtain a lethal dose (Swift 1998), which may increase the risk that some rodents may survive if the baiting strategy does not allow for an adequate period of exposure. Incidentally, these properties (such as lower persistence in the food chain) make diphacinone baits more suitable than baits with brodifacoum for sustained control projects.

These differences in non-target risks of the two toxins appear widest for terrestrial mammals and birds but the field-monitoring evidence for marine habitats suggests there is little risk of toxicity to fish and shellfish resulting from aerial application of brodifacoum for island eradication (Fisher et al. in press) or from diphacinone in the same context (Gale et al. 2008).

Three bait formulations are registered for aerial use against insular rodents for conservation purposes in the USA (two with brodifacoum and one with diphacinone) and only one (diphacinone) has been permitted for use in Hawaii by the State's regulatory agency (the Pesticides Branch of the Hawaii Department of Agriculture (HDOA PB)).

Therefore, there would be considerable advantages if aerially applied diphacinone baits could be used reliably to eradicate exotic rodents from islands where non-target animals are present and potentially at risk.

Baits with diphacinone have been used in less than 40 eradication attempts and only once to date successfully using aerial methods (on the small Hawaiian island of Mokapu where *Rattus exulans* was eradicated in 2008). Aerial broadcast baiting on three larger Japanese islands in the Bonin group failed in 2008, and was repeated on these islands and three additional ones in 2010 – outcomes from these second attempts are still pending (Appendix 1 and 2).

An analysis of previous eradication attempts against five species of rodents on islands using different toxins where the methods used and outcomes were known, and were not potentially confounded by natural re-invasion, is presented in Appendix 2. When both aerial and ground-based delivery methods are pooled across all species, 19.6% of 184 attempts using brodifacoum failed, while 31.8% of 22 attempts using diphacinone failed. This difference is not statistically significant (Fisher's Exact Test  $P = 0.26$ ). The two toxins have similar failure rates for ground-based operations (29% for brodifacoum and 23% for diphacinone; Fisher's Exact Test  $P = 0.77$ ). The limited evidence suggests aerial baiting using brodifacoum has a lower failure rate (10 of 93 attempts) than for diphacinone (4 of 5 attempts) (Fisher's Exact Test  $P = 0.01$ ). However, we caution against drawing firm conclusions about these

differences because of the small sample sizes for the aerial diphacinone attempts (see Appendix 2 for further discussion on these results and the caveats on them).

The Lehua project managers had the successful Mokapu Island project as a precedent for aerial broadcast use of diphacinone baits, so the decision to proceed on Lehua Island with this method was justified, if still experimental.

### **3 Objectives and approach**

The objectives of this review as contracted and revised at a Lehua Rat Eradication Partners Meeting on 16 April 2010 are to:

- (a) Review the planning, implementation and monitoring of the Lehua rat eradication project, including:
  - The sub-project on rat genetics
  - Evaluation of biosecurity plans
  - The aerial baiting permit and conditions requiring that no bait entered the sea, and whether this succeeded
  - Non-target-animal residue testing
  - Outreach and communications timeline
- (b) Suggest changes that would improve the likelihood of success in the future.

To address some of these objectives in a constructive way we note that the failure to eradicate the rats might be due to one or more causes (see section 7). We can describe these potential causes and speculate on which might be given more or less weight, but since we cannot ‘test’ each in retrospect, our conclusions are by nature diagnoses rather than proofs or disproofs. We recommend how some potential causes might be given more (or less) weight by additional trials and research, but again this just reinforces the diagnoses and cannot change their fundamental nature as our opinions.

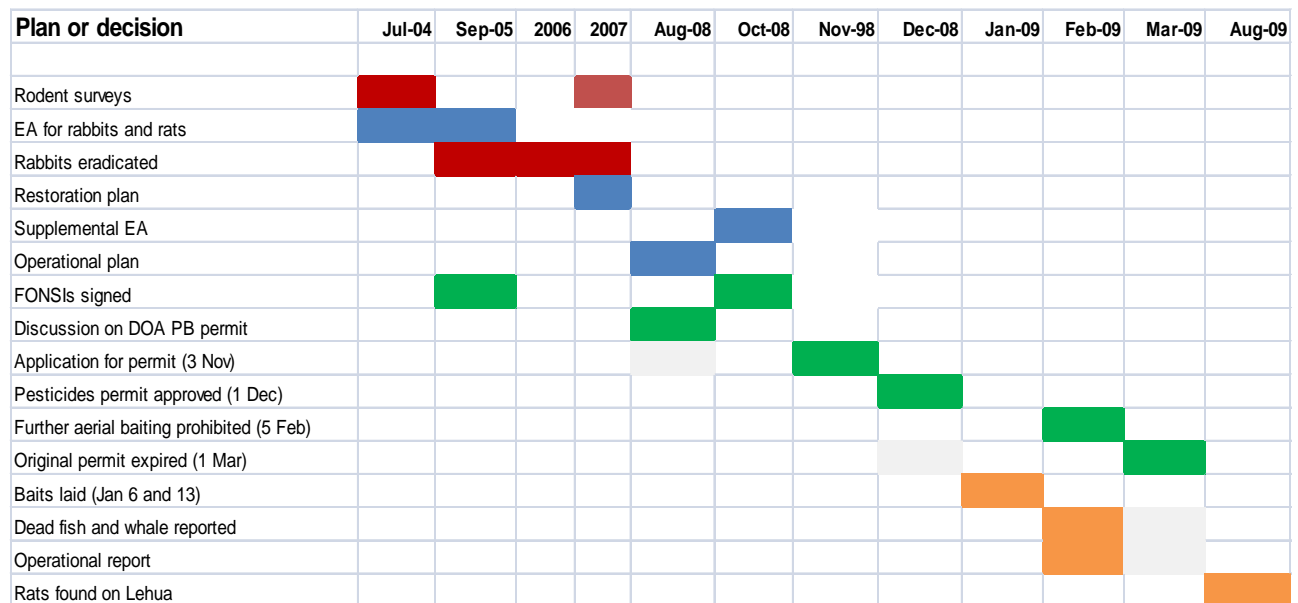
## **4 Planning**

### **4.1 Project management**

Formal written planning for the project was thorough but it appeared that the different components did not always occur in the optimal sequence – which may have led to some of the structural issues and contradictions we identify in this review (Fig. 1).

Project leadership and management was complex. Financially, the project was managed by the US Fish and Wildlife Service (USFWS) as co-lead agency who contracted the operational work to the US Department of Agriculture Wildlife Services. However, the island is Federal property administered by the US Coast Guard with the eradication and restoration projects agreed to under a Memorandum of Understanding between the Coast Guard and USFWS. Military operations in the vicinity impinged on the logistics of the rat eradication project as they required that all personnel be absent from the island at night. The island is also a State

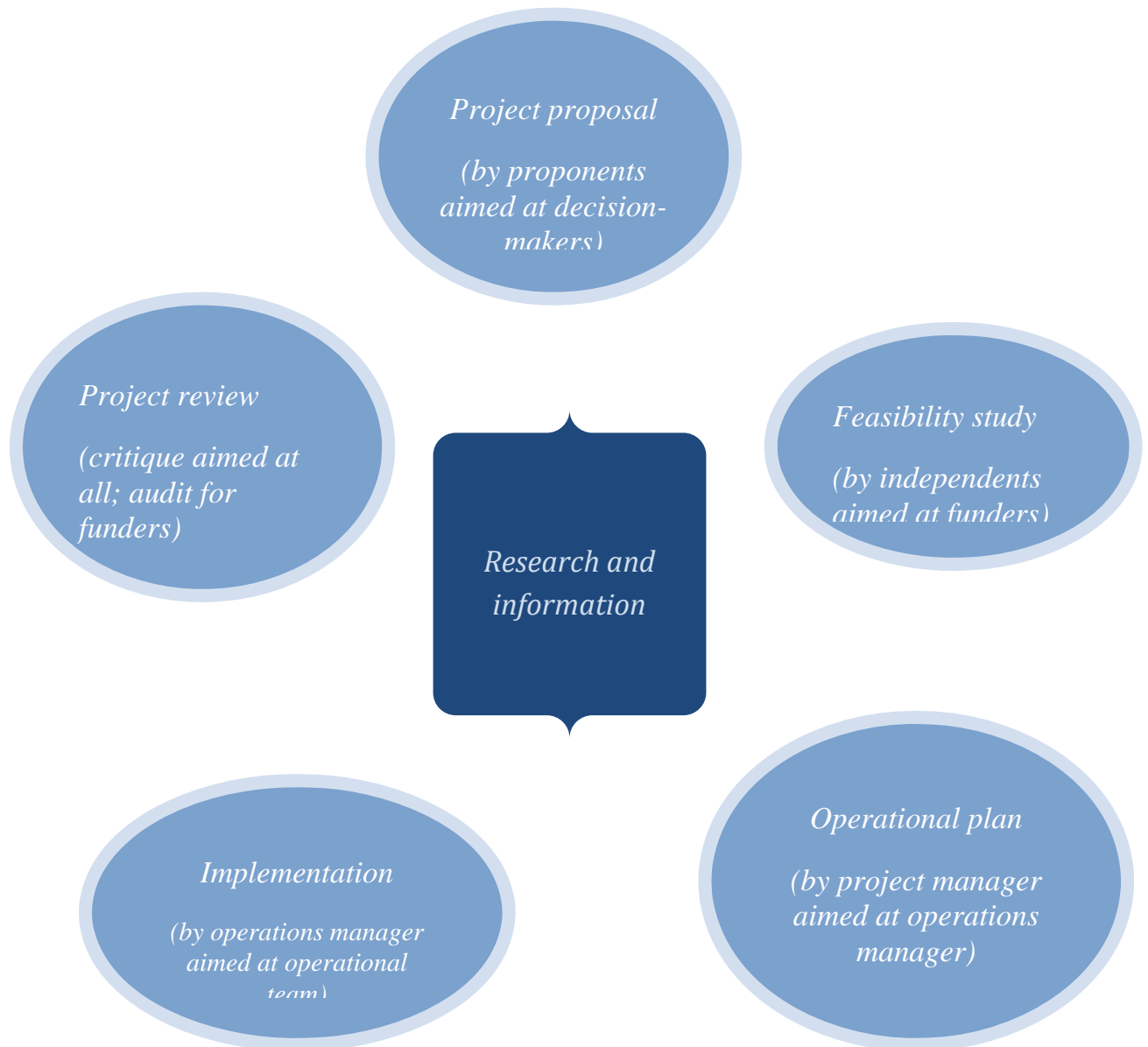
Seabird Sanctuary and a Conservation District so the State of Hawaii Department of Lands and Natural Resources Division of Forestry and Wildlife (DOFAW) was a designated co-lead agency.



**Fig. 1** Timeline of planning documents, regulatory consents, actions and events during the Lehua Island rat eradication project.

Other agencies have either regulatory responsibilities (the Federal Environmental Protection Agency for the basic registration condition to use rodenticides and Hawaii Department of Agriculture Pesticides Branch for State conditions on its use, DOFAW for access permits), or provide advice or services (Hawaii Department of Health and US Geological Survey for toxicology testing), or represent stakeholders and users.

In general, management of project components (Fig. 2) should allow the nature of who does what for whom to be transparent and so identify who is accountable at each point. The Environmental Assessment process in the USA seems to combine elements of the project proposal, feasibility and operational planning steps of a project and thus aims at a varied set of regulators, funders and operational staff. This can set up blurred boundaries for these decision makers if decision timetables become out of order or events require flexible responses. The changes between intentions in the Supplementary EA to react promptly to any failure and the Operational Plan (the latter produced before the former) to monitor in July, events and outcomes that required information and flexibility to act, and the lack of funding and capacity to deal with these biological and regulatory events constrained the project operational managers at critical times. The lesson for the project managers is that they have to align their information from monitoring with a capacity to respond to unpredicted events, for the funders that they need contingency funds to allow for such responses, and for regulators to accept some risk that might accrue from unpredicted events and the need for project managers to respond and only step into the process again after initial permits are granted if these risks are outside some range of acceptability.



**Fig. 2** Project cycle model to illustrate purpose and audience of components of an eradication plan.

## 4.2 Baseline data collection

Biological surveys of the island (Caum 1936; Wood et al. 2004) were conducted on Lehua Island after the arrival of rabbits and rats, i.e. there are no pristine baselines. Both mammals undoubtedly had adverse impacts on the native biodiversity of the island and their eradication was thus justified in the Environmental Assessments (EAs). The rabbits were eradicated by shooting and trapping between late 2005 and late 2006 (Anon. 2007a). The identity of the rats (confirmed as only *Rattus exulans*) and data on their relative densities were obtained in surveys conducted in 2004–2007 (Doratt & Driscoll 2004; Doratt 2007; and unpubl. USDA WS file notes).

Vegetation surveys and bird surveys were set up in 2002. These indicated that invasive plant species had increased in number (6 in 1931 to 27 in 2002) and now dominated the vegetation (Wood et al. 2004), and two seabirds had been extirpated (VanderWerf et al. 2007).

#### **4.3 Justification for eradicating rabbits and rats**

The benefits of eradicating rabbits and rats (and the consequences of not doing so) were justified in an EA (Anon. 2005), and again in a Supplemental EA produced in 2008 (Lee & Dunlevy 2008) modified to cover just the rats – i.e. the rabbits having been eradicated in 2005/06.

These justifications were also reiterated in a wider island restoration plan (Anon. 2007b) produced in 2007 by the USFWS and Hawaii Department of Land and Natural Resources Division of Wildlife and Forestry that received wide stakeholder endorsement via the Offshore Islet Restoration Committee.

#### **4.4 Legal permits and compliance**

The EAs covered the requirements of procedural laws (the National Environmental Policy Act) and demonstrated compliance with other Federal environmental requirements. We make no comment on these issues (other than the generic comments in section 4.1) as they are outside our expertise.

The actions proposed (alternative 2, see below, as well as the mitigation and monitoring intended) by the USFWS and Hawaii DNLR in both the 2005 and October 2008 EAs were assessed as having no significant impact to physical and biological resources in FONSI signed by USFWS in 2005 and October 2008. However, the final nature of the proposed actions could not be finalised until the Hawaii DOA Pesticides Branch had set conditions in the State aerial broadcast permit in addition to those required in the EPA Restricted Use Pesticide label. Discussions on these conditions appear to have started in August 2008, an application was made on 3 November 2008, and the permit was signed on 1 December 2008 with an expiry date of 1 March 2008 [sic] – presumably this expiry date was meant to be 1 March 2009.

Among other things, the EPA label for diphacinone aerial baiting sets the maximum application rate for two broadcasts, allows for further applications in the areas where rodents are known to survive, restricts broadcasts to times when the wind speed is less than 35 mph, and requires ‘appropriate steps to limit exposure to and impact on nontarget species, especially those for which special conservation efforts are planned or ongoing’. The DOA Pesticide Branch decreased the allowable wind speed to 25 mph and required that baits not be ‘applied directly to water’ – as with the earlier conditions in the permit issued in May 2008 for the aerial baiting of Mokapu Island. This condition apparently led to a decision not to apply baits within 30 m of the water, but this was an operational consequence of the ‘no baits directly in the water’ condition, not an additional regulatory rule. The permit application proposed that up to two extra broadcasts of bait might be used if there was evidence of rats surviving the initial broadcasts. This response is permitted under the EPA label, and as no extra conditions to restrict this possibility were set in the State permit it could have been



applied (given evidence of survivors) at least up to the imposition of a ban on further aerial broadcasts on 5 February 2009.

The coincident fish and whale deaths observed after Lehua operations (see section 6.6) and reconsiderations of events that had occurred before the Lehua permit was approved – the death of non-target feral pigs after the use of diphacinone baits in bait stations in an off-label manner at Keahou Ranch in 2003 and whale deaths after the Mokapu Island project – led the State regulatory agency (DOA PB) to instruct its staff (on 5 February 2009) not to authorize any further aerial applications of rodenticides. It is not clear to us when this instruction was known by the project managers. Also a recent US court decision ruled that an NPDES permit is required when pesticides are applied in ways that will allow the pesticide into waterways. In any event, the expiry date on the permit was intended to be 1 March 2009, so a further permit would have had to be obtained to apply the extra broadcasts if none of the above had happened and if the monitoring proposed in the Operational Plan in mid-2009 had revealed the presence of survivors.

#### 4.5 Operational intentions

The regulatory process led to some changed operational intentions.

The 2005 EA presented three alternative management options for the rats:

1. Do nothing.
2. Apply diphacinone baits followed by brodifacoum baits IF some rats survived the initial application.
3. Apply brodifacoum baits.

Aerial and hand broadcast baiting or baiting in bait stations were noted as potential techniques to apply the baits, but aerial broadcast was favored for Lehua Island in part because the topography of the island with its steep tuff slopes makes access on foot difficult and dangerous. In 2005, Hawaiian agencies chose diphacinone baits over brodifacoum as the primary control tool based on an US EPA assessment (Erickson & Urban 2004), local research on the efficacy and non-target risk of diphacinone (e.g. Swift 1998; Lindsey & Mosher 1994) and overseas issues with non-target species and brodifacoum (e.g. Dowding et al. 2006). Thus, alternative 2 was selected at this stage.

The 2008 revision of the EA also favored alternative 2 but placed a caveat (p.10 and p. 33) on the use of brodifacoum in that it would be used only **IF** ‘... it could be shown that the sole reason for eradication failure was due to the use of the rodenticide diphacinone and no other factor ...’. In any event, the use of brodifacoum was not going to be possible in Hawaii and all subsequent planning replaced this contingency (rats survived the diphacinone broadcasts) with options to repeat the broadcast of diphacinone baits. Part of the motivation for this has been the desire to prove the efficacy and safety of diphacinone baits for use on the main islands. This argument risks confusing the needs of an eradication strategy (with essentially one-off use of the toxicant) with the needs of a sustained control strategy (where the toxicant has to be applied at intervals or continuously in perpetuity). Proof of success in eradication provides only limited information on the complexities of intervention and sustained use of the toxicant on mainlands.

Other operational changes in the 2008 EA were to:

- Move the timing of the eradication from mid-summer to mid-winter based on consideration of the effect of predicted rainfall on the rats' food supply and numbers. Best practice is to bait when rats are not breeding, are hungry and (if possible) when fewest non-target species are on the island. December to February seemed to best fulfill these conditions (Dunlevy 2008).
- Not to use a deflector on the bait sowing bucket. This device has been used in some operations to direct baits inland when the helicopter is flying along the coast, but in this case the plan argued that it caused problems with bait integrity and quality and adequate dispersal from the hopper and did not work.
- Give the project manager and helicopter pilot some flexibility on the best flight paths to achieve coverage.
- Allow aerial baiting adjacent to coastlines to put all rats at risk.

A draft operational plan was produced in May 2007 (not seen by this review) and reviewed externally by the New Zealand Department of Conservation's Island Eradication Advisory Group in June 2007. The final operational plan was produced in August 2008 (Dunlevy 2008). The operational plan (p. 12) intended that if rats survived immediately after the first two broadcast baitings and/or if there were no baits left on the ground (see section 6.2), then up to two additional aerial broadcasts of diphacinone baits would be applied. The timing of these extra broadcasts was not explicit in the operational plan but tentative dates of 20 and 27 January 2009 were specified in the application for a permit to apply baits sent to the HDOA PB on 13 November 2008. As the final permit applied no conditions to this contingency and the dates preceded the 5 February ban on further aerial broadcasts, both could have occurred if monitoring had revealed survivors and funding had been available.

#### **4.6 Monitoring intentions**

Monitoring of bait quality was planned before the baits were deployed on Lehua Island. Bait distribution was to be monitored on the ground to ensure the desired coverage.

Post-operation, the original intention to measure whether any rats survived was to radio-collar 30 rats before the first broadcast and see any were still alive some time later (presumably soon after the last baits had disappeared). Too few rats were present in early 2009 before the operation to catch 30 animals, and in any event the probability that any would survive, given likely kill rates and provide any evidence of general survivorship on which to trigger further action is very low.

This left monitoring of residual bait availability after each broadcast, and especially the last, and monitoring for rat sign or presence as potential triggers for the additional broadcasts (see section 6).

Monitoring for sign of survivors (night vision, traps, tracking tunnels, etc.) was not intended to take place until July 2009 (Dunlevy 2008) or August 2009 (Dunlevy 2009), but in the event it was the discovery of one rat near the camp in August 2009 by a party researching birds and subsequent monitoring over a wider area that showed that rats were present at least

around the camp site. Subsequent monitoring found more rats and triggered a more extensive survey and debate on what to do next (see section 6.3).

#### **4.7 Biosecurity and quarantine**

There is always a risk that rodents might invade Lehua Island either accidentally from shipwrecks or as stowaways in stores, equipment and other material taken to the island. We note the genetic diversity of Lehua Island rats is lower than those at Hilo (on Hawaii) suggesting few invasion events may have occurred on Lehua Island (Piaggio & Hopken 2009). Deliberate reintroduction as an act of sabotage is possible but the motivation for anyone to do so is obscure.

Appendix D in the 2005 EA noted some risk-goods and pathways whereby new species might reach Lehua Island, and noted the need for a response to any vessel grounding on or near the island. This is all good so far as it goes – the question is whether a more formal prescription for reducing these risks should have been planned and imposed?

The 2008 Operational Plan noted this wider biosecurity intention but only concentrated on the risks imposed by the operational needs of the rat eradication – inspection of material and equipment to be taken to Lehua during the rat eradication.

There are wider biosecurity protocols in use in Hawaii for restoration projects (e.g. phytosanitary standards and guidelines used in military reserves being restored on Oahu). There is also a Lehua Island biosafety and visitor protocol that asks visitors to inspect material before landing on the island, pack gear in rodent-proof containers, etc.

If rats were eradicated the question is whether a more rigorous quarantine system is justified by the risk. Such a system would entail special facilities both at sources where equipment can be unpacked and stored in a rodent-proof (and insect-proof) room overnight, and on the island where it is again inspected in a contained facility. The first is the key in reducing risk, while the second is embarrassment safeguard against the faux pas of unpacking a rodent on the island and not being able to catch it. There are models around the world that could act as templates for an enhanced system, but the extra costs would have to be balanced against the extent to which this would actually reduce risks in the case of Lehua – probably quite a bit for the easily regulated pathways (approved visitors) but not at all for casual visits by fishermen.

Responding to shipwrecks is highly case-specific. What sort of vessels are likely to have rodents, what is the likely response time if any vessel grounded or sank nearby, and what capacity should be maintained by the response team in the event of a reported event? We do not know, but note the rat-spill contingency capacities being developed in the Aleutian Islands for a high-risk area (e.g. Ebbert et al. 2007).

#### **4.8 Public outreach**

The use of toxins, particularly when they are broadcast aerially is always contentious and the project agencies began consultations with the wider public as early as 2003 when rabbit eradication was the target. A program of outreach, particularly to Niihau and Kauai residents,

was planned but diverted after the operation by the fish deaths and the failure to eradicate the rats.

## **5 Implementation**

### **5.1 Baiting**

The broadcast application of baits was well implemented. The January baiting was within the predicted ideal window of opportunity and, apart from some minor glitches in the timing of arrival of a barge as the offshore staging facility for the helicopter for the second drop, went as planned.

In retrospect the unexpected heavy rainfall event in December 2008 and subsequent plant growth (Fig. 3) may have meant that earlier timing would have been better. It is one possible factor to be considered in the survival of rats, but we do not think it should have been a ‘stop’ event for the operation (see section 7).



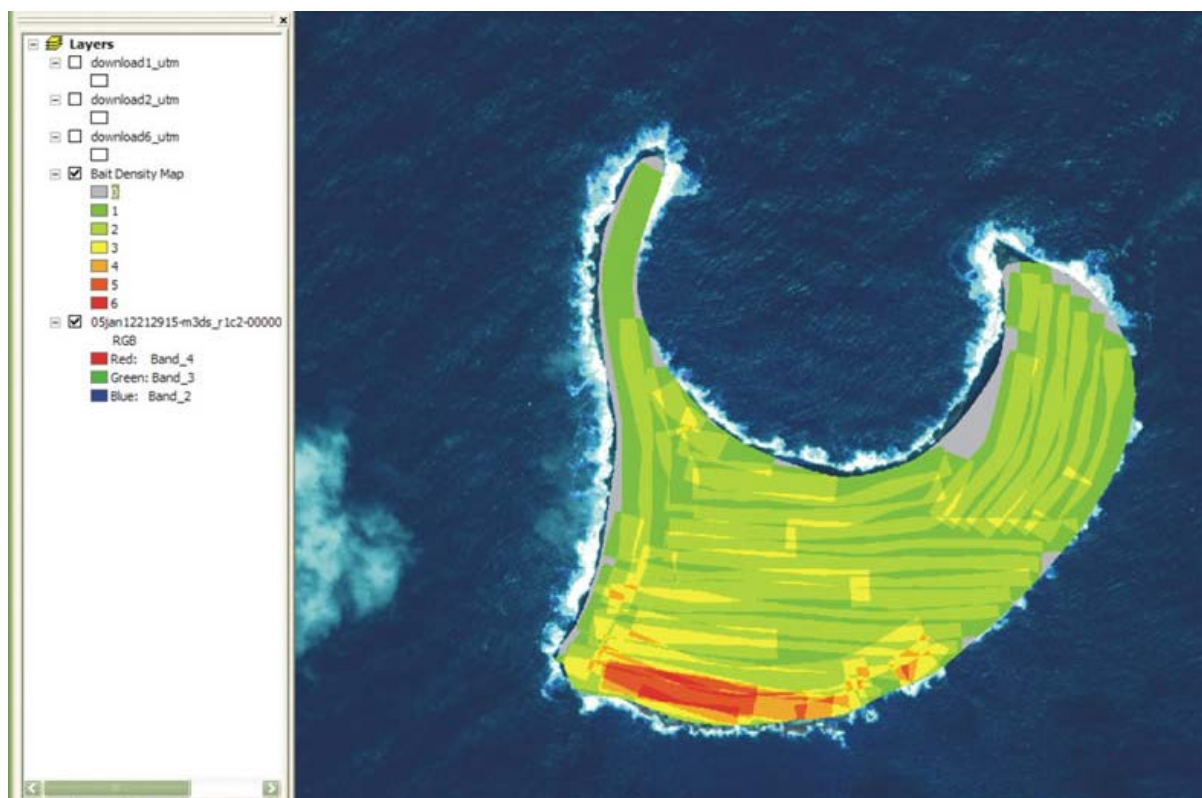
**Fig. 3** Effect of a December 2008 rainfall event on the vegetation of Lehua Island. The lower photograph was taken in January 2009 at the time of the baiting, and the top one in September 2009.

The GPS flight paths (Fig. 4) suggest reasonable coverage was achieved. However, further analysis of the swath widths suggests there may have been gaps in coverage (Fig. 5). The grey areas around the eastern part of the island were not baited in the first sowing, and judging by the flight paths were only partially treated in the second sowing. Note we do not have access to the bait density map for the second sowing but the flight paths again suggest a gap – a planar gap of about 100 m. Apparently this area is a tidal platform swept by high seas so it is probably not significant as a gap in coverage.



**Fig. 4** GPS flight paths of the helicopter sowing baits. Above (6 January 2009), below (13 January 2009). Bait was nominally sown 40 m either side of these flight paths.





**Fig. 5** Bait coverage and overlaps of flight swaths (see Fischer & Dunlevy (2010) for the methods used to calculate bait coverage). Grey = no bait sown, green through yellow to red = increasing bait densities as swaths overlapped.

There was no mention in the operational plan or report of how the condition that no baits should be applied directly to water would be or were met. The permit required no baits should fall directly into the sea, so references made to the review team about a 30-m buffer zone around the coast (and repeated in the contracted objectives for this review) were presumably operational decisions to meet this condition and made after the operational plan was written. Note: the HDOA PB reiterated (28 April 2010) that they did not explicitly require a 30-m buffer.

## 5.2 Public outreach

The EA was released for public review in July 2008 and used as a base document to solicit public comment at small-group meetings and a public meeting held on Kauai to present the restoration and rat eradication plans. A major outreach program was implemented before the operation and a response program to the post-operational events was conducted (Appendix 3).

All this support (qualified or enthusiastic) can come to nothing if key stakeholders remain outside the process. This seemed to be the case with the owner (and perhaps some residents) of Niihau Island who, however difficult that may have been, should have been informed at an early stage. It is not clear whether their eventual objections were to the goal (eradicating rats) or to the means (aerial baiting), and whether this was a priori or evolved and was articulated only after the observed fish deaths. Apparently the owner (Mr Robinson) is not averse to conserving biodiversity on Niihau but is averse to government agencies in general and

specifically in his part of the world. It was suggested to us that involving the Aha Kiole for Niihau at an early stage may have assisted with keeping the residents of Niihau better informed.

Neither of the authors of this report are experts in public outreach. However, in cases where the relationship with the wider public is passive (Boudjelas 2009) it seems wise to first have all stakeholders clearly understand what is intended and why, but unwise to join in ongoing debates with those who cannot be reconciled to the plan of action – this generally just further polarizes their views. Many invasive species programs recognize the dangers of a passive approach and adopt more active input – provision of information in the planning stages, joint decision-making, active participation in the work, to leading the operation (Boudjelas 2009). Depending on where the Lehua rat eradication now goes, it seems sensible to move along this spectrum.

## **6 Monitoring Results**

### **6.1 Bait quality**

Rodenticides registered for commercial use in the USA may contain a bitter agent (denatonium benzoate or ‘bitrex’) to deter accidental ingestion by children. However, the formulation used on Lehua Island (EPA Registration 56228-35 – a diphacinone-50 fish flavored, weather-resistant 12-mm-diameter pellet bait manufactured by Neogen Corporation HACCO Inc. with a tradename of Ramik® Green) was required without the bitter agent. The unintended presence of bitrex or lower than specified concentrations of diphacinone may compromise the success of an eradication operation by deterring rats from eating baits or requiring them to eat more baits to obtain a lethal dose, respectively. Baits can also ‘sweat’ in the bags, leading to growth of fungi that may affect bait palatability. All three of these events have occurred elsewhere in the world and so the operational plan intended to perform quality assurance checks to ensure bait specifications and quality were met.

The operational plan specified testing of 10 random samples of bait for analysis of diphacinone concentrations at two laboratories before the baits reached Kauai Island. Random bags of bait were to be opened once the baits arrived in Hawaii (on Oahu) and the bait quality checked. This was to be repeated on a weekly basis until the baits were sown. This was not done until after the operation when three random samples were sent to one laboratory (USDA Wildlife Services’ National Wildlife Research Center).

A 50-g sample of bait from each broadcast bucket load was collected and stored as a reference sample.

We have not seen the results of these tests confirming diphacinone concentration in the baits and the absence of bitrex. Note: the Ramik® Green baits used on Mokapu had the correct amount of diphacinone (Gale et al. 2008) so we assume the same for Lehua.



## **6.2 Field-life of baits**

One possible risk from the use of multi-feed toxins such as diphacinone is that not enough bait survives for long enough (generally or at some sites) for all rats in an area to obtain sufficient exposure. This of course is one reason why at least two sowings of bait is thought to be important – no gaps in time as well as no gaps in space. For example, dominant rats may sequester most of the baits leaving subordinate rats without enough baits to ingest a lethal dose. In fact this is largely untested in past eradication projects and single broadcast operations at least with brodifacoum (e.g. Norway rats on Campbell Island, New Zealand) have succeeded.

Lack of exposure in the baited areas seems unlikely on Lehua given the sowing densities, the double baiting and the low rat densities at the time of baiting. Numbers of baits were monitored on 3 days after the 6 January drop and on 2 days (up to 19 January) after the 13 January drop. In all cases plenty of baits remained on the surveyed plots – between 45% and 100% of the original numbers (Jay Nelson, unpubl. data). Therefore, unless the 20 sample plots were not representative it is unlikely that rats survived in baited areas because the last rats ran out of baits to eat.

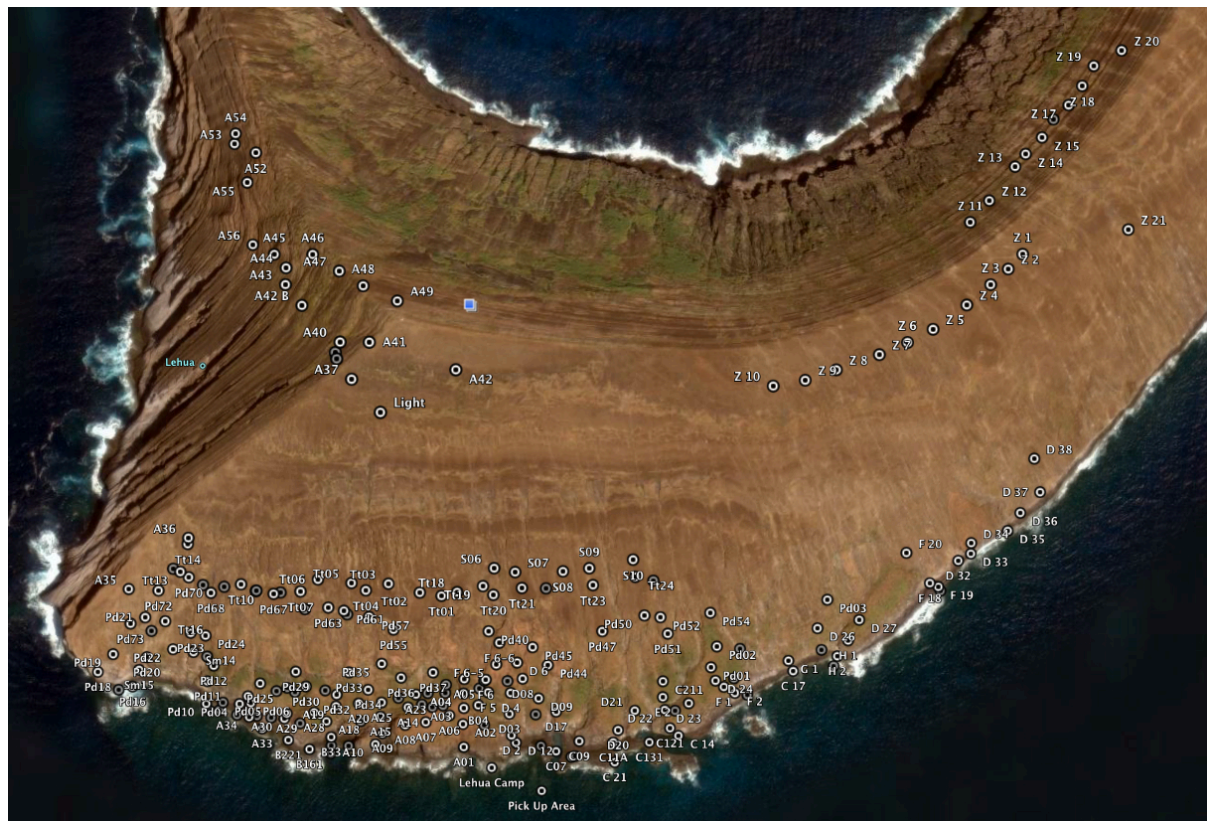
However, it would be of general interest to know the temporal and spatial patterns of bait uptake, (and thus decline), and of toxic bait life, degradation and decay due to weathering and invertebrate activity, to inform future operations.

## **6.3 Detecting survivors**

People had been on the island after the January operations to monitor baits until 20 January, and then five times between early May and late July working on seabirds and revegetation projects. However, no formal searches for rat survivors were made until after the first rat was found by chance in August 2009.

Seabird researchers were on the island and working at night with spotlights in late June 2009. No rats were seen in the area about 500 m around the camp site (L. Young, pers. comm.). In mid-August seabird researchers were again on the island for a week and saw and killed one rat at the camp site. Traps were set but no further rats were caught or seen. By the time the eradication team returned in September, rats were more abundant and widespread (Fig. 6). We note earlier data showing high trap-catch indices in June and September but very low trap-catch indices for rats in March. Very little evidence of rats was noted in January 2010 (Burney & Kanahele 2010).

Once rats had been discovered in August, the question was how widespread they were given the implications for how the follow-up use of diphacinone should be deployed. The EPA label notes that bait use should be limited to areas with sign of rats. Figure 5 shows the location of rat traps during the survey period after September 2009.



**Fig. 6** Location of rat traps deployed after September 2009 (unpubl. data from P. Dunlevy).

The project team reported 2790 trap-nights caught 128 rats, most within 150 m of the camp site, most within 80 m of the coast, and none on the north or west side of the island (including the apparent gap on the shore platform) in an unspecified period after September 2009. Presumably the age, sex and breeding status of these rats was recorded but we have not seen the data.

#### 6.4 Genetic identity of rats

USDA National Wildlife Center analysed the genotypes of rats collected before and after the baiting and compared them with a sample taken from Hilo on Hawaii (Piaggio & Hopken 2009). Basically, the pre- and post-baiting Lehua rats were genetically similar but different (and less diverse) from the rats from Hilo. This suggests that the pre- and post-baiting rats from Lehua could be from the same population and thus the post-baiting rats may be survivors rather than immigrants.

However, this tentative conclusion could be strengthened if rats from the most likely source islands (Kauai and Niihau) are also tested. If they are the same as the Lehua rats then no conclusion can be made, but if they are distinct then the conclusion that rats survived the baiting would be strengthened. It may be possible to analyse the familial relationships among the rats sampled after the operation to estimate the likely population size (i.e. number of survivors) of the founding population.

The pre-baiting sample sizes and numbers of variable loci are low so unless more pre-baiting archived samples can be found and explored for more low-frequency alleles, or the Niihau and Kauai rats are clearly different, the conclusions might remain tentative.

## **6.5 Environmental and non-target testing for residues of diphacinone**

Environmental monitoring of samples of soil, seawater, fish, limpets and crabs for diphacinone concentrations was undertaken as specified in the EA and operational plan. The sampling protocols outlined were thorough and aimed to minimize the chance of sample contamination, tampering or degradation. These appeared to have been well followed after the application of bait, with analyses undertaken by two internationally recognised laboratories, using validated methods with corresponding method limits of detection and percent recovery certainties. Extraction process appeared appropriately modified according to sample type.

The sample types taken here addressed some of the regulatory or community concerns about the contamination of the marine environment, particularly seafood that could be consumed by people. Taking environmental samples post-eradication and testing them for anticoagulant residues adds time and cost to an operation. Especially in cases where there is little theoretical basis to expect environmental residues, e.g. anticoagulants in seawater, the eradication personnel concerned are to be commended for recognizing the value of such monitoring in acknowledging pre-eradication concerns about specific contamination sites, and in being able to confirm the pre-eradication risk assessments. These data will provide important information for risk assessment for future eradications.

The samples were analyzed between 9 February and 14 April and the last of the results were not notified to the project manager until 15 May with a formal report produced after that (Orazio et al. 2009). Normally this would have been no problem, but given the fish deaths in February 2009 it may have been helpful to those dealing with that event to have had these negative results earlier. However, existing environmental monitoring data from the Mokapu Island diphacinone baiting supported the predicted assessment of no effect.

## **6.6 Post-baiting contingency response to fish kill on Niihau**

Planners could not predict the monitoring contingency that emerged as the result of a ‘fish kill’ on Niihau Island after baiting on nearby Lehua Island. Aerial application of diphacinone bait over Lehua Island occurred on 6 and 13 January 2009. The exact date of the fish kill is unknown, but according to reports from Ni‘ihau, the dead fish were noted between mid- to late January.

Speculation on the possible causes of the fish kill included the use of toxic baits on Lehua Island, some unspecified factor resulting from an unspecified military exercise conducted nearby in January and February, and a land-based pollutant being washed into the sea. A memo from DLNR Division of Aquatic Resources (Oishi 2009) noted that none of these really explained the nature of the fish kill as only a few fish species were killed although all putative causes must have exposed most species. There was evidence of a toxin from freshwater blue-green algae in the stomachs of some fish, so this might have given a little weight to the land-based-runoff theory. Against the diphacinone theory is the fact that no

residues were found in any of the dead fish (or others taken alive) and logically one would expect that the larger the kill, the less likely it could have been caused by the limited number of baits that may have fallen into the sea. The media release on the 3 June 2009 was careful to report that no rodenticide was detected in any fish sampled and that other causes of the deaths were being investigated.

However, in the interim while the causes were being investigated, some community attention focused on the coincidence of diphacinone bait application on Lehua and fish mortality observed on Niihau, to make cause-and-effect associations. The implication of diphacinone contamination of the marine environment, particularly the concern that fish commonly taken for human consumption might be contaminated, received attention from a range of reporting media and social networking forums. While various agencies concerned (see below) undertook appropriate investigations to confirm whether diphacinone was involved and identify other potential causes of the fish mortality, their response (on 3 June) was outpaced by media and Internet coverage, and by alarmist presentations (see [http://sdces.sdstate.edu/ces\\_website/conferences/2009wrpm/Western\\_States\\_Meeting\\_2009.pdf](http://sdces.sdstate.edu/ces_website/conferences/2009wrpm/Western_States_Meeting_2009.pdf)), all of which served to convey a message of an adverse outcome of the Lehua operation that was not borne out by the eventual test results.

In terms of validity of the testing, the several fish sampling and analyses of tissues by independent laboratories represent very good practice, conducted with high quality assurance and with the universal ‘below-detectable-limit’ results clearly indicating that the fish and whales had not been lethally exposed to diphacinone, and almost certainly not at all.

Pre-eradication assessments had not identified significant risk to the non-target species from the use of diphacinone. While association of the mortalities with aerial application of rodenticide bait was eventually ruled out through residue testing and expert consultation, this meant that staffing and resources were diverted in order to respond to an unexpected public relations requirement. Undoubtedly the negative connotations being promoted, and the speed at which this occurred, created added pressure for planning and operational staff soon after the bait application. This has perhaps not been an issue for past eradications because they have been on islands remote from human populations. Islands such as Lehua, that are far more ‘visible’ to the public, provide a valuable indication that formal post-baiting communication and media strategies should predict and be ready for similar attention, and that residue testing should be undertaken as quickly as possible to address concerns and ‘cause-and-effect’ claims. We suspect that despite thorough outreach and risk communication in the planning and consultation stages before aerial bait application, post-operational attention of this nature will be inevitable for islands that are inhabited or close to large human populations.

## **7 Diagnosis of eradication failure**

### **7.1 Rats were eradicated but reinvaded?**

All the rats may have been killed on Lehua Island by the two baitings and those found in August 2009 were new rats. Polynesian rats are poor swimmers and are not known to have self-colonized any islands more than 65 m from source populations (Atkinson & Towns

2005). The nearest source population to Lehua Island is on Ni'ihau Island, the latter some 1200 m away.

So, if the rats found were new colonists they must have arrived accidentally on a boat or aircraft or have been deliberately released.

Preliminary comparisons between 18 pre- and 24 post-baiting rats on Lehua Island suggest that they are from the same population and that the post-baiting animals are most likely survivors (Piaggio & Hopken 2009). However, tests of rats from Kauai (and hopefully Niihau) will be needed to determine whether there is any allelic differences between the Lehua Island rats and those from these neighboring islands – i.e. immigration can only finally be ruled out if the rats from the other islands have different allelic patterns.

## **7.2 Rats survived due to an operational issue?**

### **Bait specifications and quality**

The bait manufacturer has a good reputation and provided guarantees of bait quality, but so far as we know no independent assay of bait quality was conducted by the project managers. We assume it was of good quality and had the specified toxic loading.

### **Time of year**

The operational plan changed the timing of the operation from mid-summer (the 2005 EA) to mid-winter (December–February) to coincide with least breeding by the rats, lowest plant diversity and biomass, and fewest non-target birds. Apparently for logistical reasons (staff availability over Christmas) and presumably legal reasons (the final State permits were not signed until 1 December) the operation went ahead in early January. Unfortunately, it rained in December and the vegetation grew (Fig. 2). This may have compromised the operation by triggering breeding in the rat population or by providing competing natural food that lowered the acceptance (= percentage of rats that eat baits) of the baits or reduced the number of times rats fed on the baits.

The diet of Polynesian rats appears to contain more plant material (fruit, seeds and green parts) than other rat species. For example, on Kure Atoll 62% of their diet was plant material, including the fruit of *Scaevola* spp. which is also present on Lehua Island (Wirtz 1972). On Lady Alice Island (northern New Zealand) 78% by volume of the species' diet consisted of plant material (Newman & McFadden 1990). Note: the eradication of the rabbits also resulted in a vegetation response (Eijzena undated) so as a more general rule the order in which invasive species are eradicated is an issue (e.g. Parkes 2009).

Some rodent eradication projects test for bait acceptance before the toxic baits are used by looking at whether 100% of a sample of animals from a population exposed to non-toxic baits with a bait marker actually eat them (e.g. Wanless et al. 2009). If seasonality and competing natural food is an issue, any future attempts might conduct such a trial.

### **Spatial gaps in baiting**

There were gaps in the distribution of baits (Figs. 3 and 4) caused by the requirement that no baits fell directly into the sea. The way the pilot flew the baiting swaths apparently left up to

30-m buffers from the coast. We do not know whether any unplanned gaps in the GPS flight paths were identified on the day and remedied immediately.

Home ranges of Polynesian rats on Lehua Island are not known but on other islands range diameters of 12–78 m (on Kure Atoll; Wirtz 1972) and at least 36–60 m (on Tiritiri Matangi Island, New Zealand; Nicholas 1982) have been measured. Clearly some Lehua rats may have avoided exposure if they had home ranges as small as those on Kure Atoll.

Curiously, the areas with the most extensive swath overlaps and so most bait were those where the surviving rats were first discovered, so if the gap hypothesis is correct the rats found around the camp in August 2009 had to have dispersed from the gap site(s). The bird survey teams on the island in August 2010 were out at night and working over much of the island, so if rats had been widespread there was a chance (probability unknown) that any present would have been seen.

### **Temporal gaps in bait availability at baited sites**

There were plenty of baits remaining on sample plots between the broadcasts and for at least a week after the second broadcast. Therefore, unless some drastic event occurred after the 19 January sampling that destroyed the baits or made them unpalatable it is unlikely that bait availability at the baited sites was a problem. We note the general lack of information on this whole area in aerial broadcast baiting for rodents. The planning assumption seems to be that any problems are overcome by ‘over engineering’ the delivery with excess baits – despite the potential added risks to non-target species and environmental contamination that might accrue.

### **7.3 Rats survived because of the bait and toxicant used?**

One of the obligate rules for eradication is obviously that all individuals in the target population must be exposed to risk of death (Parkes & Panetta 2009). It is possible that a few rats simply do not eat the baits (unlikely from previous studies) or do not eat baits on enough days over a week or so to obtain a lethal dose (the precedents discussed in Appendix 2 suggest this is not a universal problem).

Previous work with Ramik® Green diphacinone baits in Hawaii showed that all Polynesian rats caught ( $n = 23$ ) after exposure to non-toxic baits broadcast by hand had eaten baits (Dunlevy et al. 2000). However, more recent work has shown that Ramik® Green only killed 40% of *R. exulans* exposed to baits and alternative non-toxic foods over 7 days although it killed all rats when they had no choice of foods, and was generally of lower efficacy against all three rodent species tested (*M. musculus*, *R. exulans* and *R. rattus*) than the second-generation anticoagulants and one other first-generation anticoagulant (chlorophacinone) (Pitt et al. 2010). In the field on Lehua Island the rats would have been exposed for longer than 7 days, but had a choice of bait or natural food so the bait and toxicant per se cannot be ruled out as a cause of failure. Precedents are few so a more controlled experimental design would need to be applied to test this option.

If the rats could not obtain this continuous supply of bait there could be an interaction between the multiple-feed requirements of diphacinone and the baiting strategy. That is, how the baits are deployed in time and space may not allow all rats the opportunity to obtain a

lethal exposure if either timing or distribution leaves a ‘gap’, or if competition from natural foods is acute and discourages a few rats from eating sufficient baits.

If we assume a large Lehua rat weighs 60 g (Doratt & Driscoll 2004), and the maximum diphacinone exposure to kill all such rats is 15.9 mg/kg (unpublished data cited in Swift 1998), such a rat would need to eat 0.954 mg of diphacinone, which is contained in 19.08 g of bait, or about 10 of the baits used; and it would have to eat these over at least 7 days judging by the results in Pitt et al. (2010). The availability of baits (see section 6.2) in baited areas that were sampled suggests exposure over at least a week after the last drop was not an issue. However, note the issue we raise about the dangers (for eradication) in basing decisions on the ‘average’ rat.

Gaps without any baits were left and it is possible that even if they were smaller than resident rats’ home ranges that such residents were not exposed to enough baits often enough at the edges of their ranges, i.e. an interaction between rat behavior and the mode of action of diphacinone, and one disadvantage over single-dose anticoagulants where this possibility is reduced.

## **8 Conclusions**

1. Where no terrestrial non-target species are either exposed to or at risk from toxic baits there is little advantage in using diphacinone over brodifacoum. The risks to marine non-target species are low or absent for brodifacoum, and probably low or absent for diphacinone.
2. Where non-target species (especially birds) are exposed and at risk to brodifacoum there is a real advantage in using diphacinone baits. This is both to save the costs of mitigation and to avoid the political costs of non-target deaths with consequent restriction of options to manage rats on islands.
3. The desire to link successful eradications and successful sustained control operations on the main islands in Hawaii to demonstrate the benefits of using diphacinone requires some care. The strategies require different interventions (one-off vs. ongoing), have different outputs (no pests vs. lowered densities of pests), different outcomes (no impacts vs. some ongoing impacts of the pests), and different environmental risks from the toxicant (time limited vs. ongoing).
4. The planning for the Lehua operation was complicated and proposed actions and methods changed during the process as either the lead-agency and operational agency changed their views, or as external agencies imposed conditions. Not all intended actions were delivered.
5. The actual operation was conducted to plan given limitations on capacity and constraints imposed by regulators.
6. The intention to react if rats survived was not well developed. There was no search for survivors during the time when a response with repeat aerial baitings was permitted. By the time rats were discovered the impetus (funding, capacity and clear lines of decision) had declined, and the policy climate (brought to a head by the fish deaths) had made a response impossible using aerial broadcast and more difficult if other methods were to be considered.

7. A search for survivors to trigger follow-up responses would not have been simple, with few rats potentially left and no information on detection probabilities. The sensible approach would be to be precautionary and plan for more baitings (especially when diphacinone is used) and stop when the probability of survivors given searches that find none is very low. However, the EPA label required evidence of survivors to trigger such a response. This is an area deserving of research investment – if you search and find none what is the probability that none are there and will this probability satisfy the regulators?
8. Diagnosis of the cause of failure is difficult. We assume the bait quality was good and the rats were not immigrants. The recent results from Pitt et al. (2010) give some cause for caution around the use of Ramik® Green baits as an eradication tool (not however for sustained control where some survivors are not a problem). However, given the past successes with diphacinone baits including Ramik® Green other causes are also possible. Again, given the effect of alternative food on mortality rates shown by Pitt et al. (2010) the interaction between the flush of natural food on Lehua and the mode of action of diphacinone (multiple feeds over many days) may have meant some rats were not killed. From perusal of the small maps on bait coverage, the presence of bait for some time after each broadcast and the location of survivors in areas that had been well baited, it seems less likely that spatial or temporal gaps in bait availability were the cause.

## **9 Recommendations for the future**

1. The EPA label requirements for repeat applications of diphacinone need to be revised to allow for a precautionary approach, i.e. further broadcasts or other applications should be permitted unless there is a clear absence of survivors. Managers need to invest in developing monitoring methods with known detection characteristics that can be applied soon after the second aerial baiting that give a high probability that any survivors would be detected, to enable a reactive approach to be triggered or to provide evidence of absence.
2. Studies need to be conducted to address public and regulatory concerns about the risk of diphacinone baits to marine fish. We do not think this is a real risk but regulators and the public need to be convinced. It is hard to see how one would do similar tests on cetaceans or pinnipeds, but common sense suggests exposure is highly unlikely and hazard is zero.
3. An analysis of the outreach program to assess the changed perspectives among those who might naturally support a rodent eradication as a step to improving the island's biodiversity and those who might focus more on the operational risks would be worth doing to inform future projects.
4. Given the explicit experimental nature of aerial broadcast with diphacinone, pre-operational field trials using non-toxic baits with a bait marker would help to determine if the abundance of natural food is likely to compromise success. A quantitative bait marker would have to be used to determine lethal acceptance rates for diphacinone baits.
5. A ground-baiting operation using either hand-broadcast baiting or bait stations (or a mix of both) seems the only practical way forward on Lehua Island in the short term. Diphacinone baits have a good chance of success with this method providing coverage is sufficient to give all rats a chance for long-term exposure to baits. The constraints on this method are that the island is topographically difficult yet all bait



stations or baited sites will need to be maintained with a certain supply of baits for several weeks, i.e. multiple visits will be required.

6. If the aerial broadcast method is to be repeated the operation should not start if natural food is abundant. This would require flexibility in planning, funding and regulatory processes. If the permits require no baits fall directly in the sea remains, either the coastal gap should be baited by hand broadcast or bait stations and/or the behavior of coastal rats should be studied to determine the frequency with which they venture into potentially baited areas. This could be done by telemetry studies or by the use of bait markers in non-toxic baits. Finally, a protocol to detect and map the location of survivors would need to be developed to enable the reactionary application of further baiting – unless the EPA label conditions can be changed to allow for a precautionary approach. Developing a search and detection protocol with sufficient power to find and locate survivors with high confidence is not a trivial task.
7. The complex governance and decision-making processes involved in planning, regulating, delivering and monitoring the Lehua Island project need to be streamlined in future projects so that who does what for whom is transparent. The nature of the relationship between the proposing and funding agencies (USFWS and DOFAW) and the delivery agencies was essentially one of client and contractor. Whose role should it be to manage the relationships with regulators or with stakeholders? This was not always transparent and it appears some of these functional relationships were not covered.
8. More generally, it appears that the tested double-baiting strategy used for aerial application of brodifacoum baits cannot be simply copied for diphacinone aerial baiting. More complex data on ensuring exposure time for all rats than have been gained in the trials conducted for sustained control operations will be required. Put simply, LD50s and average exposure requirements are relevant to sustained control but LD100s and the tails of distributions are critical for eradication.

## **10 Acknowledgements**

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## Appendix 1. Previous attempts at rat eradication using diphacinone baits

<sup>1</sup>Bait stations and hand broadcast baiting with brodifacoum also failed in a further attempt in 2006 (Pierce 2007). <sup>2</sup>Brodifacoum baits were also used. <sup>3</sup>Islands close to source populations so immigration likely. <sup>4</sup>The unknown capacity of the monitoring used in the Bay of Islands to detect surviving rats made it difficult to interpret lack of evidence data after these operations as rats were subsequently found on all islands. <sup>5</sup>No sowing bucket was used in these Japanese operations; the baits were simply broadcast by hand out of a helicopter.

Island	Area (ha)	Rodent spp.	Year	Method	Days bait eaten	Eradicated?	References
<b>USA Islands</b>							
Mokoli'i	1.5	<i>R. rattus</i>	2002	Bait stations, traps		Yes	Smith et al. (2006)
Mokapu	4	<i>R. exulans</i>	2008	Aerial		Yes	
Steven Cay	0.8	<i>R. rattus</i>	1983	Hand broadcast		Yes	
Dog Cay	4.8	<i>R. rattus</i>	1983	Hand broadcast		Yes	
Kalkun Cay	1.4	<i>R. rattus</i>	1982	Hand broadcast		Yes	
Buck (St Croix)	72.7	<i>R. rattus</i> <i>M. musculus</i>	2000	Bait stations, hand broadcast		Yes No	Witmer et al (2007)
Buck (St Thomas)	16.8	<i>R. rattus</i> <i>R. norvegicus</i>	2005	Bait stations, hand broadcast		Yes	Pierce (2007)
Dutchcap Cay	12.9	<i>R. rattus</i>	2004	Bait stations, hand broadcast		Yes	Pierce (2007)
Saba	12.3	<i>R. rattus</i>	2003	Bait stations, hand broadcast		Yes	Pierce (2007)
Capella	9	<i>R. rattus</i>	2005	Bait stations, hand broadcast		Yes	Pierce (2007)
Egmont Cay	112	<i>R. rattus</i>	2009	Bait stations, Hand broadcast		Yes?	
Congo Cay	10.6	<i>R. rattus</i>	2004	Bait stations, Hand broadcast		No <sup>1</sup>	Hall et al. (2006)

Cocos (Guam)	33.6	<i>R. exulans</i> <i>M. musculus</i>	2009	Hand broadcast, some bait stations with brodifacoum trapping		Yes? <sup>2</sup>	
Cormorant (Bay of Islands, Alaska) <sup>3</sup>	2.1	<i>R. norvegicus</i>	2003	Bait stations, spot baiting	133	No	Dunlevy & Scharf (2007) <sup>4</sup>
South (Bay of Islands, Alaska) <sup>3</sup>	11.4	<i>R. norvegicus</i>	2003	Bait stations, spot baiting	83	No	Dunlevy & Scharf (2007)
Green (Bay of Islands, Alaska) <sup>3</sup>	22.4	<i>R. norvegicus</i>	2003	Bait stations, spot baiting	106	No	Dunlevy & Scharf (2007)
Camouflage (Bay of Islands, Alaska) <sup>3</sup>	4.3	<i>R. norvegicus</i>	2004	Bait stations	75	No	Dunlevy & Scharf (2007)
Black (Bay of Islands, Alaska) <sup>3</sup>	1	<i>R. norvegicus</i>	2004	Bait stations	c. 60	No	Dunlevy & Scharf (2007)
Sweet (Bay of Islands, Alaska) <sup>3</sup>	0.5	<i>R. norvegicus</i>	2004	Bait stations	c. 30	Yes?	Dunlevy & Scharf (2007)
Ina (Bay of Islands, Alaska) <sup>3</sup>	4.5	<i>R. norvegicus</i>	2004	Bait stations	70+	No	Dunlevy & Scharf (2007)
Aureola (Bay of Islands, Alaska) <sup>3</sup>	0.3	<i>R. norvegicus</i>	2004	Bait stations	70+	No	Dunlevy & Scharf (2007)
Duh (Bay of Islands, Alaska) <sup>3</sup>	0.1	<i>R. norvegicus</i>	2004	Bait stations	70+	No	Dunlevy & Scharf (2007)
Earl (Bay of Islands, Alaska) <sup>3</sup>	6.4	<i>R. norvegicus</i>	2004	Bait stations	70+	No	Dunlevy & Scharf (2007)
Bubba (Bay of Islands, Alaska)	0.5	<i>R. norvegicus</i>	2004	Bait stations	<30	Yes?	Dunlevy & Scharf (2007)
North Rocks (Bay of Islands, Alaska) <sup>3</sup>	0.7	<i>R. norvegicus</i>	2004	Bait stations	27	Yes?	Dunlevy & Scharf (2007)
Channel (Bay of Islands, Alaska)	2.9	<i>R. norvegicus</i>	2004	Bait stations	25	Yes?	Dunlevy & Scharf (2007)
<b>Other countries</b>							
San Jorge Sur (Mexico)	5	<i>R. rattus</i>	2000	Bait stations	c. 10	Yes	Donlan et al. (2003)

Canna (UK)	1130	<i>R. norvegicus</i>		Bait stations	Yes	Bell et al. in press)
Nishijima (Japan)	49	<i>R. rattus</i>	2007 2010	Bait stations Aerial <sup>5</sup>	No ?	Hashimoto (2010) Harrison (2010)
Mukojima (Japan)	268	<i>R. rattus</i>	2008 2010	Aerial Aerial	No ?	Hashimoto (2010) Harrison (2010)
Torishima (Japan)	11	<i>R. rattus</i>	2008 2010	Aerial Aerial	No ?	Hashimoto (2010) Harrison (2010)
Higasijima (Japan)	28	<i>R. rattus</i>	2008 2010	Aerial Aerial	No ?	Hashimoto (2010) Harrison (2010)
Anijima (Japan)	785	<i>R. rattus</i>	2010	Aerial	Pending	Harrison (2010)
Otoutojima (Japan)	530	<i>R. rattus</i>	2010	Aerial	Pending	Harrison (2010)

## Appendix 2 Summary of all rodent eradication operations by species and method used

Since 1971 eradication of rats (*Rattus rattus*, *R. tanezumi*, *R. norvegicus*, and *R. exulans*) and mice (*Mus musculus*) has been attempted on about 489 islands (plus associated stacks and islets) from 27 countries. About 13% of islands required more than one attempt. Up to 93% of the islands treated are free of rodents – the real success rate is unknown but lower than this as outcomes are unknown of about 10% of the islands and reinvasion on others is certain.

In this analysis we treat each population of each species as the unit (rather than an island each of which may have more than one species) and compare success rates at each attempt when different toxins are used in two broad delivery methods – aerial baiting and ground baiting. Aerial baiting is generally by broadcast application using a helicopter with a sowing bucket. However, in a few attempts (e.g. the Japanese attempts using diphacinone as the toxin) the baits were simply sown by hand from the helicopter along the flight paths. Ground baiting covers a multitude of methods from hand-broadcast baiting (in an attempt to cover the whole island), to trail baiting along transects, to a grid of bait stations at various distances apart where the baits are either laid in piles open to the environment or placed in covered bait stations of various sorts. Thus, a caveat we put on the results presented here is that we may not always be comparing like with like and further analyses would have to be made to test these variables.

For *Rattus exulans*, a total of 98 eradication attempts on 93 islands have been made between 1978 and 2010 with outcomes and methods reported for 86 of the attempts (Table a). Little Barrier (Hauturu) Island (3083 ha) in New Zealand has been the largest from which the rats were eradicated using aerial broadcast brodifacoum in 2004. Kure Atoll (105 ha) in the Hawaiian chain has been the largest from which the rats have been removed using ground methods – a mix of hand-broadcast baits with brodifacoum or bromethelin toxin and trapping. Aerial baiting with brodifacoum has a perfect success rate, but ground methods have been more variable. There are too few attempts using diphacinone to draw any conclusions – the Lehua Island attempt failed while the Mokapu Island attempt succeeded, and there have been no ground-based attempts at eradicating *R. exulans* using diphacinone baits.

For *Mus musculus*, a total of 73 attempts on 63 islands have been made between 1971 and 2009 with outcomes and methods reported from 63 attempts. Coal Island (1163 ha) has been the largest from which mice have been eradicated using aerial brodifacoum baits in 2008 (final confirmation of success is expected in 2011). Selvagem Grande (270 ha) in the Madeira islands in Portugal is the largest from which mice have been eradicated using ground methods – bait piles and hand-broadcast using brodifacoum baits. Success with brodifacoum has not been good for mice, with 28% and 47% of aerial and ground attempts failing, respectively. Diphacinone has not been used deliberately against mice. The single failed attempt being revealed once rats had been removed from Buck Island (Table a).

*Rattus exulans* and *M. musculus* are very poor swimmers so all attempts have been included. However, for *R. rattus* and *R. norvegicus* a similar analysis is complicated by these rats' swimming ability. Islands close to source populations are likely to be reinvaded and so interpretation of the immediate success or failure of an eradication attempt can be difficult to determine, especially if no immediate (and believable) check is made after the operation. Later evidence of rats may indicate operational failure or success followed by reinvasion. In the analysis used here we have attempted to avoid the uncertainties caused by potential



reinvasion by only considering eradication attempts on islands or close groups of islands that are further than 1000 m from potential source populations. The data on swimming distances require further work to validate and clearly depend on the species and water temperatures. This rule cuts out many attempts from this analysis where reinvasion was highly probable, e.g. the 18 islands with *R. rattus* and *R. norvegicus* in the northern Bay of Islands in New Zealand where brodifacoum was used and the 13 islands in the Bay of Islands at Adak in Alaska with *R. norvegicus* where diphacinone was used. In both cases the resident rats may or may not have been removed and reinvasion was inevitable.

**Table a** Number of eradication attempts with known outcomes (see the text for explanation) for five rodent species using aerial and ground-based systems to deliver baits containing different toxicants. Data from Howald et al. (2007) and updated from J. Parkes (unpubl. data).

Rodent species	Toxicant	Aerial distribution		
		No. attempts	No. failed	% failure
<i>R. exulans</i>	Brodifacoum	38	0	0.0
	Diphacinone	2	1	50.0
<i>M. musculus</i>	Brodifacoum	25	8	32.0
	Diphacinone	0		
	Bromadiolone	3	1	33.3
	Flocoumafen	1	0	0.0
	Mixed	1	0	0.0
<i>R. rattus</i>	Brodifacoum	15	2	13.3
	Diphacinone	3	3	100.0
<i>R. norvegicus</i>	Brodifacoum	15	0	0.0
		Ground distribution		
		No. attempts	No. failed	% failure
<i>R. exulans</i>	Brodifacoum	37	11	29.7
	Diphacinone	0		
	Bromadiolone	4	1	25.0
	Flocoumafen	1	0	0.0
	Mixed	4	1	25.0
<i>M. musculus</i>	Brodifacoum	19	9	47.4
	Diphacinone	1	1	100.0

	Flocoumafen	2	1	50.0
	Pindone	3	1	33.3
	Warfarin	1	0	0.0
	Mixed	6	2	33.3
	1080	1	1	100.0
<i>R. rattus</i>	Brodifacoum	17	4	23.5
	Diphacinone	10	2	20.0
	Bromadiolone	4	1	25.0
	Coumatetralyl	1	0	0.0
	Pindone	4	0	0.0
	Mixed	8	1	12.5
<i>R. tanezumi</i>	Brodifacoum	1	0	0.0
<i>R. norvegicus</i>	Brodifacoum	17	2	11.8
	Diphacinone	2	0	0.0
	Bromadiolone	6	1	16.7
	Chlorophacinone	1	0	0.0
	Difenacoum	2	1	50.0
	Warfarin	2	0	0.0
	Strychine	1	0	0.0
	Mixed	4	1	25.0

Over all five species of rodents tallied in Table a, brodifacoum baits distributed from the air have succeeded in eradicating the target population 83 times in 93 attempts and distributed from the ground in 65 times in 91 attempts. Diphacinone baits have succeeded in eradicating the rodents once in five attempts using aerial baiting, and 10 out of 13 attempts using ground-based methods of delivery. Fisher's Exact tests suggest brodifacoum is significantly better than diphacinone when baits are distributed from the air ( $P = 0.019$ ) but the small sample size for aerial diphacinone would need to be increased before we could be very confident about this result. There was no significant difference in success rates between the two toxins when baits were applied in the various ground-based methods ( $P = 0.77$ ). If all attempts are pooled brodifacoum failed in 19% of attempts while diphacinone failed in 40% of attempts. Fisher's Exact Test shows this result is not significantly different ( $P = 0.26$ .)

Our conclusion from this analysis is that diphacinone baits applied in ground-based delivery mechanisms works as well as brodifacoum baits delivered in a similar way. The validity of the comparison between the aerial use of the two toxins is unclear, especially as the three attempts that failed in the Ogasawara Islands used a different aerial method to spread baits than is usual (see above).

### Appendix 3 Timeline of meetings and outreach for the Lehua Island project

- Dec. 2003** USFWS and partners developed an Outreach/Media Strategy for the Lehua Island Restoration Project Phase I – Rabbit Eradication.
- Dec. 2004** USFWS and partners developed a full-color fact sheet for the Lehua Island Ecosystem Restoration Project (**Revised 2008**) placed on USFWS website.
- June 2005** USFWS and project partners send out joint news release – ‘Public Comments Sought on Draft Environmental Assessment for Proposed Ecosystem Restoration Project on Lehua Island’.
- NEPA Scoping Process Public Meeting held at the Lihue Neighborhood Center on June 8. The meeting had no agenda; however, a record of attendance was kept along with notes containing public input. In addition, the Service provided an informative fact sheet on Lehua Island to meeting participants.
- Nov. 2005** USFWS and partners developed a Q&A fact sheet (internal document) to answer media questions about Phase I – Rabbit Eradication on Lehua Island.
- Apr. 2008** Thomas Kaiakapu and Chris Swenson met with Jacqueline Kozak, Kauai-based Outreach Specialist for the Hawaii Invasive Species Council, to draft an outreach plan in preparation of the Supplemental EA release and public meeting in July.
- Identified stakeholders to contact (listed below).
  - Established outreach timeline for May 2008 – January 2009.
  - Identified educational products for branding restoration efforts and reaching out to the Niihau community.
- May 2008** Initiated outreach efforts by contacting stakeholders, developing educational products and branding slogan, and began collaboration with Ke Kula Niihau o Kekaha.
- Worked with USFWS to update fact sheets on rodents and Lehua restoration.
  - Designed new fact sheet on Lehua rodent eradication project that announced public meeting date.
  - Worked with Hokulani Cleeland to translate flier into Niihau dialect.
  - Met with Principal and high school teacher of Ke Kula Niihau. School decides to take on Lehua as a class project and offers to help with outreach to Niihau community.
  - Scheduled Mike DeMotta, from NTBG, to present to the high school students about the restoration and eradication plans.
  - Began contacting all of the stakeholders and partners via phone, email, mail, and direct meetings.

- Collaboratively identified a Hawaiian slogan (*E ola hou o Lehua...Lehua will thrive again*) for the project and designed magnets to be distributed at outreach events and meetings.
- Kaiakapu begins attempts at reaching out to Robinson family and trying to set up a meeting.

**June 2008** Continued communications with stakeholders and began connecting the school with NTBG for vegetation restoration involvement.

- Gave a public presentation at NTBG about eradication plans.
- USFWS and partners revised Offshore Islet Restoration Committee (OIRC) fact sheet and placed on OIRC website.
- Communicated with dive operators and recreational boaters by direct visits.
- Worked with Ke Kula Niihau to plan for their involvement in the public meeting. Student composed an *oli* about Lehua restoration.
- Distributed translated fliers to Niihau ohana through school

**July 2008** Prepare for and conduct public meeting about Supplemental EA.

- Worked with USFWS to draft a press release about the public meeting. News release – Lehua Island Ecosystem Restoration Plan Available for Public Review ‘*Public Meeting to be held on Kauai*’.
- USFWS and partners developed a full-color fact sheet entitled ‘Facts about Rats’ and posted on the USFWS website.
- Posted fliers at all community boards, boat harbors, and other key stakeholder sites.
- Called and emailed key stakeholders to remind them about and personally invite them to the public meeting.
- Work with the school to plan for opening *pule* and continue announcing the meeting to the Kauai-based Niihau community.
- Public meeting was held on 24 July at the Waimea Community Center with presentations from the USFWS. 30+ people in attendance included Ke Kula Niihau students, some parents, and various conservation partners.

**Aug. 2008** Continue work with Ke Kula Niihau to involve the school in restoration plans and academic studies about Lehua. Include information about Lehua eradication and restoration plans in public presentations.

**Sep. 2008** Continue answering questions from interested stakeholders (referred technical questions to Chris Swenson and Katie Swift) and working with the school.

**Oct. 2008** Involve Ke Kula Niihau in Newell’s shearwater fledgling blessing (videotaped by Chiefess K. students and Cal Hirai) to make the connection to native species that will benefit from the rat eradication. Submitted press release about the event.

- USFWS and partners send out news release – Environmental Assessment for Lehua Island Ecosystem Restoration Project Finalized.
- Nov. 2008**      Begin planning next phase of outreach for scheduled January operations.
- Drafted and designed a new flier about operational plans to be translated.
  - Worked with the school and NTBG to plan blessing.
  - Scheduled announcements for new Niihau radio station .
- Dec. 2008**      Final outreach push before operations.
- Project blessing was held at NTBG on 11 December Restoration and eradication partners were present. Pastor Dan Kaohelauii of the Hawaiian church in Waimea was scheduled to offer the *pule*, but was unable to make it due to last-minute travel delays, and so the students of Ke Kula Niihau offered their *oli*. The event was videotaped and announced via direct invite and flier to the school and partner organizations.
  - USFWS and partners send out news release – Lehua Island Ecosystem Restoration Project to Begin.
  - Translated fliers were sent home with students and distributed via the school before holiday break to alert the community of the operational timeline for January.
  - Dive operators and other key stakeholders were also contacted
- Jan. 2009**      Operations were announced via press, radio, and direction communication.
- Feb. 2009**      Niihau fish kill.
- Extensive communication with the school about community reaction and concerns (answering as many questions as possible at that point)
  - Extensive outreach to the school and the community via the school and student *ohana* .
  - Communicated with stakeholders who had been involved and informed along the way
- Mar. 2009**      Set up a meeting at Ke Kula Niihau to talk with the students (who were planning to give a public presentation on their Lehua studies) and the larger Niihau community. Meeting was held on March.... USFWS, DOFAW, DAR, and NTBG were present to answer questions about the fish kill and operations. Niihau *ohana* were invited ahead of time and that day to participate. About 15 people from the Niihau community attended, mainly *kupuna*. Keith Robinson also attended.
- USFWS and partners develop a diphacinone fact sheet, which includes a timeline of events at Lehua and Niihau from December 2008 to February 2009.

- HI DLNR called for a special meeting to address media and public concerns about the fish kill. Requested USFWS draft a joint news release to address public concerns and to release immediately. For some unknown reason, DLNR pulled their support from the news release at the last minute and nothing was sent to the media or public.
- Following a flurry of media inquiries, the monitoring results were released (no diphacinone residue detected in any samples), but not in an official news release format.
- USFWS and its partners developed (internal) talking points to respond to inquiries from the media concerning the fish kill.

**Aug. 2009** Dawn initiates communication with Ilei to follow up about the fish kill.

**Sep. 2009** Met with Keith Robinson and Ilei Beniamina (Aha Kiole for Niihau) to discuss recently released DAR report on fish kill and the discovery of a rat population on Lehua. Worked with the school to brainstorm outreach ideas to address enduring community concerns about fish kill, future eradication efforts (there is opposition to any aerial operations), and community volunteer and employment opportunities in restoration.

- Met with Aha Kiole of Kauai to update about Lehua as well.

**Oct. 2009** Hawaii Division of Aquatic Resources releases ‘official report’ on the Niihau fish kill.

## **Recommendations**

- It would have been good to initiate outreach effort prior April/May 2008 to give plenty of time before the public meeting.
- We should have made more of an effort to meet with and reach out to the Robinson family.
- The Aha Kiole of Niihau and Kauai should have been involved and informed at the onset of outreach.
- More timely follow up was needed to address concerns following the fish kill.
- More direct involvement and better communication was needed among all project partners.
- There is a need to properly fund and staff outreach efforts, so staff can commit and focus.

## **Reflection**

The collaboration with Ke Kula Niihau o Kekaha was instrumental in reaching out to the Kauai-and Niihau-based Niihauan community. This relationship is ongoing and will continue to be engaged in Lehua restoration efforts. I think that this was the most positive aspect of the outreach efforts on Kauai and recommend that future eradication projects identify and engage champions, especially youth, in their plans.

## **Kauai Partner/Stakeholder Contact List**

- DOFAW (Thomas Kaiakapu, Alvin Kyono) & Seabird Recovery Project (Nick Holmes) & HCP (Andrea Ericson)
- KIUC (Reggie David)
- Kauai Humane Society (Mary Alice & Becky Rhodes)
- DAR (Mimi Olry, Don Heacock, Wade Ishikawa) & NOAA (Jean Souza)
- USFWS, Kilauea Pt Refuge, (Mike Hawkes, Brenda Zaun) & Kilauea Point Natural History Museum
- State Parks (Wayne Souza)
- NTBG (Chipper Wichman, Dave Burney, Mike DeMotta, Ken Wood)
- Kauai Watershed Alliance & TNC (Trae Menard)
- USDA NRCS (Lex Riggle) and Wildlife Services (Scott Williamson)
- HDOA (Ann Kam)
- Westside Watershed Council (Jose Bulatao, Rhoda Libre)
- Na Pali Coast Ohana (Sabra Kauka)
- Garden Island Resource Conservation & Development (Laurie Ho)

- Ke Kula Niihau (Haunani Seward), Kula Aupuni School (Myra VanOrnum)
- Robinson Family, Gay & Robinson
- Taro Growers Association, Westside
- Hanalei Watershed Hui (Makaala Kaaumoana)
- Diving & fishing tour companies
- Hawaiian Church, Waimea
- Kauai Hunting Association & Barking Sands Archery Club
- Hawai'i Fishing News
- Save our Seas, Sierra Club, SurfRider Foundation, West Kauai Rotary Club
- Hui o Laka, Kokee Resource Conservation Program
- West Kauai Soil & Water Conservation District (Howard Greene)
- Kauai Public Land Trust
- Malama Mahaulepu
- Waipa Foundation
- CTAHR
- Media: Raising Islands (Jan TenBruggencate), Garden Island (Rachel Gerhlein & Dennis Fujimoto), Valaau (Dickie Chang), Outside Hawai'i (Cal Hirai)
- Kauai County Council & Mayor Bryan Baptiste
- Blue Water Campaign
- ReefCheck
- Office of Planning, Coastal Zone Management Program (Abbey Seth Mayer) & Office of Conservation & Coastal Lands (Sam Lemmo)
- KISC, HISC, & Coordinating Group on Alien Pest Species (CGAPS)
- Pacific Missile Range Facility (John Burger)
- Roland Sagum, West Kauai Representative
- Kikiaola Land Company
- DOCARE (Terry Lo)